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THE SUCTION SOCKET ABOVE-KNEE ARTIFICIAL LEG

THIRD EDITION

PREPARED BY
PROSTHETIC DEVICES RESEARCH PROJECT
UNIVERSITY OF CALIFORNIA

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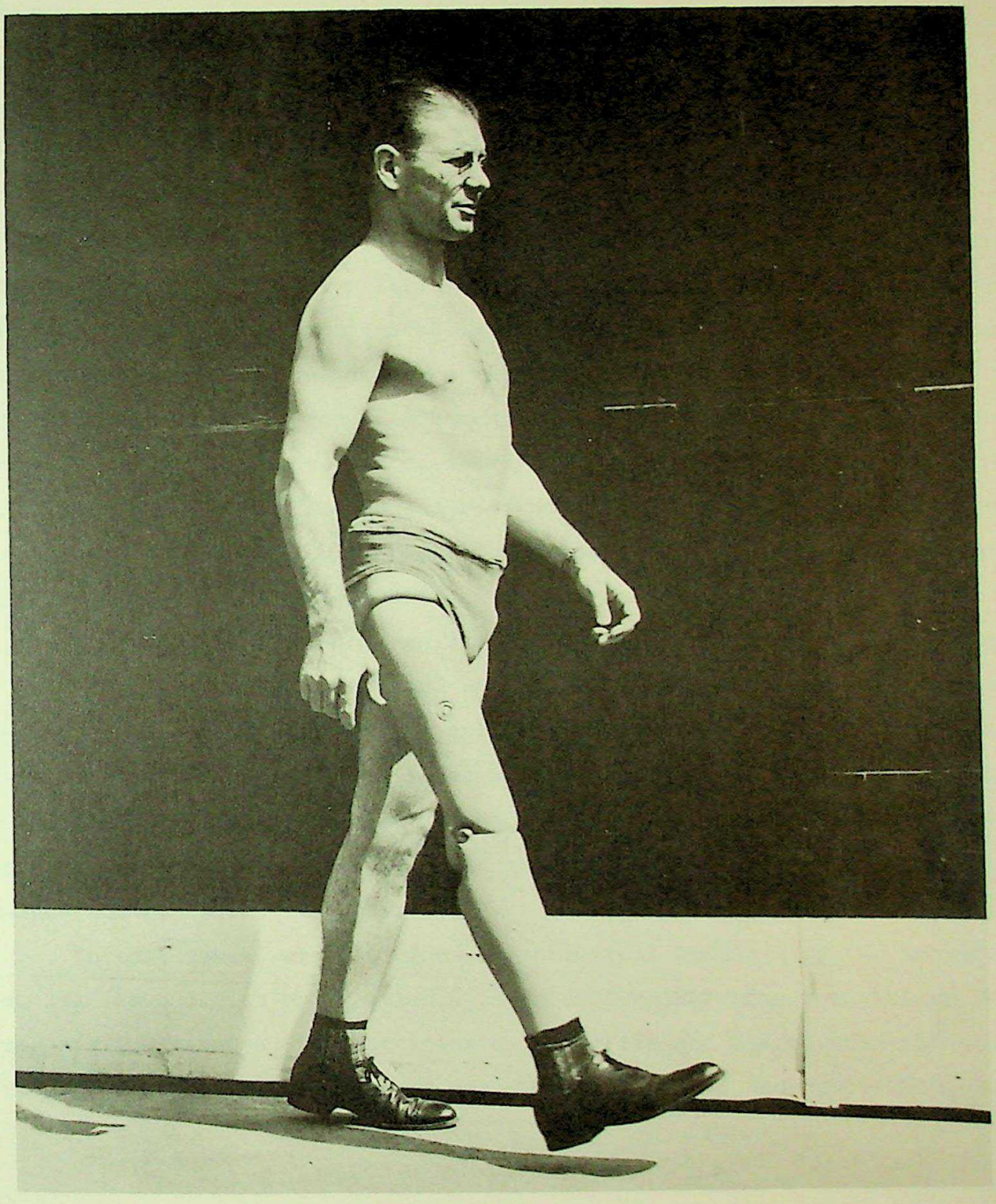


THE SUCTION SOCKET ABOVE-KNEE ARTIFICIAL LEG

The suction socket above-knee prosthesis differs from the conventional leg in that it has no pelvic hinge or suspension harness. The leg is held on by a moderate suction created in the closed socket each time the leg is lifted from the ground. As compared with the conventional leg, the suction socket permits greater freedom of movement in all directions, feels more like an integral part of the body, and does away with the discomfort of the pelvic belt. This type of prosthesis has been used in Germany for years, and has been experimentally used with consistent success by selected amputees in various parts of the United States during the past three years.

From December 1947 through January 1949, twenty short courses were held in various parts of the United States to inform limb manufacturers and orthopedic surgeons regarding the technical details of the suction-socket above-knee leg. These training periods, which were one week long, served only as an introduction to the subject since considerable experience is required on the part of the limb manufacturer and the orthopedic surgeon to fit the above-knee suction socket satisfactorily.

In this report are described the principal features of the suction-socket leg as modified by experience to date, together with suggestions for avoiding difficulties and for obtaining an effective and comfortable fit. It is a revision of preliminary reports dated September 1947 and April 1948.

HISTORY OF THE SUCTION SOCKET

The earliest known reference to the suction socket is in the form of a patent issued by the U.S. Patent Office, February 10, 1863 (Patent No. 37,637) to Dubois D. Parmelee of New York, N.Y. The principal idea was the attachment of the socket to the stump by atmospheric pressure. Subsequent patents have been issued to George C. Beacock and Terence Sparham of Brockville, Ontario, Canada, in 1885; to Justin Kay Toles of Stockton, California, in 1911; and to Ernest Walter Underwood of Birmingham, England, in 1926. Fundamental principles of the Beacock and Sparham suction socket differed but little from the Parmelee socket; Toles' description was basically the same but with the addition of a rubber tube and bag lining which could be inflated by air to assist in holding the socket on. The socket described by Underwood had smooth helical grooves which he claimed ventilated the stump as well as assisted in holding the socket in place.

A search of the literature on above-knee suction sockets has revealed only a few articles prior to the last few years. Little of England, in 1926, reported favorably on eleven amputees fitted with suction sockets designed by Blatchford and made of metal which contained a smooth helical groove of a little more than one turn around the circumference of the socket. Some thirty cases were fitted at Roehampton (England) after World War I, using the metal socket with the helical groove. It is not known whether these thirty cases included the eleven reported by Little, but it is considered doubtful as several different groups were using the suction socket in England at that time. Use of the suction socket has been practically dormant in England for a number of years, but has been revived recently.

Pfau of Berlin says the suction socket has been known in Germany for twenty-five years but was not popularized until Oesterle in Ulm started his work in the early thirties. Felix, a surgeon of Dusseldorf, reported on above-knee suction-sockets in 1941. He stated that the suction socket had been used in Germany to some extent since World War I but was not popularized until a satisfactory valve had been constructed in 1932. After this accomplishment, numerous selected cases were successfully fitted.

In 1946, the U. S. Surgeon General's Office sent a Commission on Amputations and Prostheses to Europe to observe foreign practice. One principal item of interest was the successful use in Germany of suction sockets for above-knee prostheses. The Advisory Committee on Artificial Limbs of the National Research Council then instituted a program to determine the possibilities and limitations of the suction-socket leg, as one activity of their general program of providing information regarding the best possible prostheses for the amputees of the United States. The Committee's work is sponsored by the Surgeon General's Office and the Veterans Administration and has had the cooperation of the Army and Navy Amputation Centers, many commercial limb manufacturers throughout the country, and the contractors working under the supervision of the Committee.

Recent Development in the United States

In order to determine the effect of widely diverse climatic conditions, subjects were selected in ten localities. The suction-socket legs were made by commercial limb manufacturers in general accordance with their regular materials and practices, but making use of supplementary information and supervision provided by representatives of the Advisory Committee on Artificial Limbs. The results were carefully recorded.

At the termination of the program in the ten localities on April 15, 1948, fifty-two subjects had been fitted. Forty of the subjects had been wearing the suction-socket leg regularly for four to twenty months; all were well satisfied and had no intention of returning to a pelvic-belt leg. Six of the subjects were still alternating between the suction-socket leg and the pelvic-belt leg due to improper fittings, nervous disorders, or lack of cooperation. The remaining six had been dropped from the program for personal reasons not involving the suction-socket leg.

During the twenty schools held for one week during the period December 1947 through January 1949, 250 orthopedic surgeons and 200 limb fitters were given indoctrination in the manufacture and use of the above-knee suction-socket leg. Together with the original group of ten manufacturers, this group has been responsible for successfully fitting more than one thousand suction-socket legs throughout the United States. The relatively few

unsuccessful cases that have occurred have been caused principally by improper fit due to lack of experience with this type of socket and to some extent by lack of cooperation on the part of the amputee. There is no record of a single case where medical difficulties resulted from the use of a suction socket.

CHARACTERISTICS OF THE SUCTION SOCKET

The only apparent difference between a suction-socket leg and the conventional above-knee leg is the elimination of the pelvic hinge, belt, and all suspension harness. The muscles of the stump control all movements of the leg. The leg is held on by a slight negative pressure, or suction, created in the closed socket due to the weight of the leg as it is lifted from the ground. The socket is made to fit snugly in order to maintain an air seal, but should not restrict the muscles or circulation of the stump. No sock is worn on the stump. When the socket is properly fitted and has no leaks, there is no relative motion between the skin and the side wall of the socket; the femur moves slightly within the soft tissues of the stump.

To put the suction socket on the stump, a thin sock is employed as shown by the series of photographs in Figure 1. The valve is removed, and the sock is pulled off and out through the valve opening. After the stump has been seated and is comfortable, the weight is put on the leg and the valve is inserted to seal the socket.

The suction is maintained by accurate fit of the socket. At first most fitters made the socket too tight in an effort to prevent the loss of suction. However, the tight fit led to many cases of edema on the end of the stump. With the suction socket, weight-bearing occurs about the top portion of the socket, particularly in the region of the ischial tuberosity and the gluteal muscle. The addition of a definite ischial seat reduces piston action of the stump in the socket to a minimum and allows a looser fit at the top of the socket. Incorrect shape, size, or location of the ischial seat leads to definite discomfort and to frequent loss of suction which is particularly noticeable while sitting. Corrective measures will be described later herein.

Incorrect fit leading to discomfort or burning about the ischium has been the principal cause of the failures that have occurred; and some fitters have discarded the ischial seat for this reason.

In some very muscular stumps the ischial seat must be reduced in size or removed entirely since the muscles actually push the ischial seat away from the tuberosity of the ischium. Such amputees bear weight on their well-developed muscles with the load distributed around the top portion of the socket. The socket is shaped the same except for the reduction or removal of the ischial seat.

The advantages most commonly mentioned by the amputee are:

1. Elimination of the conventional pelvic belt and hinge; the amputee has more freedom and comfort, and there is less interference with clothing.
2. The leg feels more like an integral part of the body, without the sensation of much dead weight.
3. Improved control and position sense.
4. Greater toe clearance due to greatly reduced piston action of the stump in the socket.
5. No stump sock necessary while wearing the suction socket.
6. Correction of the adductor roll, since it is pulled below the brim of the socket.
7. Active use of the stump muscles, which allows them to grow instead of atrophy.

No harmful effects from the wearing of a properly fitted and aligned suction-socket leg have been encountered. The slight negative pressure required to hold the leg on has caused no measurable change in blood circulation. The presence of edema, discomfort, or irritation of the skin around the top portion of the stump has been traced to an improper fit and can be corrected.

INDICATIONS AND CONTRAINDICATIONS

Indications

The improvement in function permitted by a properly fitted suction-socket leg makes it advantageous for any above-knee amputee. The suction socket is, however, of particular advantage in the following cases:

1. Impairment of the opposite leg, such as a stiff knee, paralysis, or amputation. Greater ease in walking is possible in these cases due to the decreased piston action and its resultant increase in toe clearance.
2. Painful scars about the crest of the ilium. Elimination of the pelvic belt allows fitting where otherwise the pressure created by the belt could not be tolerated.
3. A pendulus abdomen, due to obesity or pregnancy, which interferes with the wearing of a pelvic belt.

Contraindications

These contraindications must never be considered absolute, since under special circumstances a satisfactory fitting may be obtained in the presence of one or more contraindications. The contraindications are:

1. Active osteomyelitis.
2. A scar extending to the top of the socket, which would interfere with the maintenance of suction. Such scars can usually be repaired surgically, bringing together the subcutaneous tissues so that satisfactory suction can be maintained.
3. Serious skin condition. A dermatologist should be consulted since many of these conditions can be corrected. Chronic boils with a large amount of subcutaneous scar tissue, such as may occur in an adductor roll, are not a contraindication. A properly fitted socket which pulls this roll down inside the top of the socket will quickly relieve this condition.
4. Psychological factors. These should be evaluated, along with the total examination of the patient, to determine whether the amputee will be sufficiently cooperative for the proper fitting of the suction-socket leg.

Factors Which Are Not Contraindications

The following factors have at various times been considered contraindications. At the present time, however, in the hands of an orthopedic surgeon experienced in this field and a properly trained limb fitter, they are not so considered.

1. Associated injuries of the opposite leg. In general this is of minor importance, since the superior control of the suction socket allows easier walking. The greatly reduced piston action which provides greater toe clearance is also an advantage in these cases.

2. Deep or adherent scars below the level of the top of the socket. These may cause a pulling sensation for a time, but are not contraindications. The orthopedic surgeon should check the stump frequently, particularly during the early stages.

3. Spurs or large bone masses at the end of the stump. These conditions may usually be alleviated by proper fit at the lower part of the socket. Sharp spurs on the outer side of the stump may require surgical correction. Sufficient room must be allowed around any large bone mass to prevent excessive pressure on the muscles and skin.

4. Arterial disease with reduced circulation is not a contraindication, provided the patient is suitable for fitting of a leg of any type. The suction socket requires less work of the remaining leg, particularly of the calf muscles, than does the pelvic belt; but it may promote greater overall activity.

5. Capillary fragility is generally caused by Vitamin C deficiency, and cases have been fitted without correction of the deficiency with no evidence of edema.

6. Short stumps can be satisfactorily fitted. The amputee with a short stump and a suction socket is at a considerable advantage over one with a pelvic belt or suspender leg because of lack of piston action and the superior control afforded by the suction socket. The difficulty encountered with short stumps is loss of suction when sitting, or when getting in and out of an automobile. Proper fit and alignment will usually overcome this difficulty.

7. Extremely heavy amputees. Weight of the patient has caused no difficulty in properly fitted cases. Amputees as heavy as 245 pounds have been successfully fitted. The common error in fitting these large stumps is making the socket too small.

CONSTRUCTION OF THE SOCKET

Material

The primary requirements of a material to be used in making a suction socket are ease in forming to the proper shape, adaptability to a surface finish which is easy to maintain clean and sanitary and to which the skin is tolerant, and the possibility of making alterations as required by changes in the stump. Wood and plastic laminate have so far received the most attention. Because major changes in size of the stump generally take place during the first several months of wearing a suction socket, it is recommended that wood be used since it is relatively simple to shape and allows alterations to be made as required. After the stump size has become established, in possibly six months to a year, a socket made of plastic laminate seems preferable because of its flexibility in comparison with wood, its ability to stand cleansing with soap and hot water, and its greater resistance to the action of perspiration.

Shape

The wood socket is carved and shaped to fit each amputee individually; however, it has been found that a definite pattern can be used for the rough outline of all sockets at the level of the ischial tuberosity. The measurement of the perimeter taken through the crotch and in the gluteal crease as shown in Figure 2 determines the pattern size. Use the pattern taken or interpolated from Figure 3 that has a perimeter about one-half inch less than the measured perimeter. The pattern outlines are shown full-size in the figure and may be traced and increased or decreased for desired size. The perimeter length indicated on each pattern is the length measured around the outside of the ischial seat. The wood which forms the ischial seat lies inside this perimeter. It should be emphasized that the pattern is only a general outline and that specific modifications must be made for each individual amputee.

A study of Figure 4 will indicate the principal muscle groups and other anatomical features that were considered in arriving at the average pattern used as a guide in the preliminary layout of the socket outline. The

shape deviations will depend on muscular development, thickness of subcutaneous fat, and size of the bony skeleton. A careful examination of the stump with regard to each of these factors will aid in making an accurate pattern of the proper size and shape. In general, the greatest deviations occur for small cylindrical stumps and for large flabby stumps with little muscular development. Figure 5 shows an example of the deviations between the actual socket outline for one amputee and the pattern used for the rough fit.

It should be pointed out that the anterior side of the socket at the pattern or ischial-seat level can be undercut with respect to the superior brim above this region. This procedure is generally used on short stumps or with cases that present difficulties in maintaining suction, in order to provide greater adherence. The outline of the anterior side of the patterns shown in Figure 3 is such that sufficient wood is generally provided for finishing the superior brim and permitting the removal of additional wood beyond the pattern outline when undercutting on the anterior side. No other allowance for undercuts, which may be desirable in some cases, has been made in the typical pattern shape.

Figure 6 illustrates the steps in making the preliminary layout of the suction-socket outline. The critical dimensions to be obtained from the patient's stump are, first, the length from the adductor longus muscle through the medial side to the ischial tuberosity, and second, the distance from the medial side to the lateral side, as shown at A and B in Figure 6. With the original pattern adjusted to conform to these critical dimensions, the successive steps in completing the rough outline are shown in the remaining diagrams of Figure 6 and are described in the following paragraphs.

Medial Anterior Apex.--The socket shape in this area, shown at C in Figure 6, should conform to the contour of the adductor longus and gracilis muscles. However, the shape will vary in each case fitted, since these muscles form a cord-like tendon which can not tolerate undue pressure. Too tight a fit in this region will also tend to rotate the foot outward at heel strike. Examination of the stump will determine the pattern in each individual case.

Medial Side.--The crotch-line area that receives the adductor longus, gracilis, and adductor magnus muscles should not be so narrow in width as to crowd the adductor longus at the region of the anterior-medial apex and should be enlarged periodically in accordance with stump growth. The crotch-line height varies with respect to the ischial seat in almost every case; however, stumps that are atrophied but are able to withstand the pressure are provided with a high medial side, since very little active use of the adductor muscles is noted during the initial weeks of wearing a suction socket. A pelvic tilt lowers the ramus of the ischium and requires a lowering of the medial side of the socket. Since there is relatively little piston action in a suction socket, some weight can be borne through the medial side with no ill effect. In general, the height of the medial side is governed by comfort of the amputee in the socket. From the ramus to the anterior-medial apex, the medial side can rise, remain level, or fall, as governed by comfort. If a medial adductor roll is present the socket is enlarged on the medial and anterior sides to accommodate the excess tissue which is pulled into the socket and which eventually diminishes. As indicated at A in Figure 6, the measurement from the adductor longus muscle to the weight-bearing portion of the ischial tuberosity, less about 1/2 inch, gives the length of the medial side of the socket. This dimension can also be used for the proper positioning of the ischial seat from the anterior-medial apex.

Ischial Seat.--The importance of the ischial seat on the socket cannot be overemphasized. The seat should be accurately located under the ischial tuberosity, as shown in Figure 7, and individual variations must be taken into account. If the wood is left as large as indicated on the pattern, there will be ample material remaining for proper shaping. The seat should be adequate, but should not be so wide as to cause discomfort while sitting. Slipping of the ischial tuberosity to either the inside or the outside of the seat creates a great deal of discomfort. This may be prevented and the socket rendered more comfortable by shaping the bearing surface so as to slope the seat slightly toward the inside of the socket. This sloping increases the radius of the ischial-seat edge and lessens the burning sensation of the skin in this region.

If the ischial seat is too prominent, a jabbing sensation or a marked increase in pressure occurs near the end of the stance phase. Lowering the ischial seat allows more weight to be distributed to other parts of the socket, and -- if the ischial tuberosity is properly located on the seat -- results in less discomfort and requires a shorter breaking-in period.

Amputees with well-developed stump muscles may or may not require a definite ischial seat. In some cases the muscles actually push the ischial seat away from the tuberosity of the ischium, and the weight is carried by the muscles around the top portion of the socket. The socket is shaped as described herein except for the reduction or removal of the ischial seat. This procedure is also necessary in various unusual cases, such as end-bearing stumps with large adductor roll.

Posterior.--The back of the socket is very important in an ischial-bearing socket. Relief for the gluteus maximus muscle depends on the individual, but in most cases where there has been little atrophy or distortion, this region of the socket should be kept on the same level as the ischial seat with a gradual enlargement in the posterior-lateral apex. The gluteus muscle should carry a considerable amount of body weight.

Relief for the adductor muscles or the crotch line can often be made by relieving the gluteus maximus. Too tight a fit on the gluteus maximus can cause crowding of the adductor muscles in the crotch section. The ischial tuberosity can be moved posteriorly and laterally on the ischial seat of the socket by lowering and relieving the gluteus muscle space. However, lowering this section increases pressure on the ischial tuberosity. Should additional room be needed within the socket, the lateral side of the gluteal region can be made wider just posterior to the lateral protuberance. The gluteal area should be widened instead of cut deeper posteriorly; a deeper section will form a hump or radius on which the leg will rotate while sitting, thus causing a burning sensation of the skin under the ischial tuberosity. The effect will be even more prominent if there is an undercut below the ischial seat.

The shape of the outside of the socket in the posterior region is important with relation to sitting comfort. No attempt should be made to complece this shape until the inside has been made comfortable and the leg

has been properly aligned and tested by walking. The back is then shaped for comfort and alignment while sitting, as shown in Figure 8. For very muscular stumps having a large and well-developed gluteus muscle group, a soft-back construction (Figure 9) has been successfully used to increase sitting comfort.

Lateral Side.--The lateral or outer side is generally slightly higher than the ischial-seat level. With amputees having a short stump, additional height of the socket in this region may be required to maintain suction. The highest point on the superior brim is forward of the trochanter with a slope across the front to the medial or crotch side, but in no case should it be so high as to interfere with hip flexion or abduction.

The lateral side of the socket is undercut in some cases, depending on the muscular development in this region. This undercut may be desirable for flabby or thin stumps, but in the majority of cases the side is made fairly straight. An examination of the individual should easily determine this shape. If an undercut is used, it can start about one inch below the top and continue for several inches. Below the maximum undercut the outside should taper in somewhat, to provide support for the femur above the distal end as abduction takes place upon weight-bearing. Since the femur has been established as the body stabilizer during the stance phase, an undercut may distribute the pressure unevenly and thus allow most of the pressure to be taken at the top of the socket and below the undercut. An undercut should be used only on stumps that have trouble holding suction or as necessary to accommodate large well-developed muscles in this area.

The protuberance which is left in the socket adjacent to the back of the greater trochanter is very important in cases with atrophied or flabby stumps because of the stability it gives during walking. The location and average size of the protuberance are shown at G in Figure 6. The protuberance assists in maintaining the position of the ischium on the ischial seat, helps to resist the tendency for the leg to rotate, and aids in holding suction especially when sitting. For flabby or atrophied stumps the protuberance can be prominent and still not disturb any muscular activity, as indicated by the anatomical cross-section shown in Figure 4. However, for some firm stumps

with little subcutaneous tissue this protuberance may be very small or completely eliminated, as stumps in this condition have very good control of the leg and require no stabilizer. During the push-off phase, the lowering of the protuberance below the ischial-seat level may cause discomfort due to excess pressure; each case must be checked for individual variations when deciding on how prominent to make the protuberance. If the contact between the trochanter and the protuberance causes discomfort, relief can be obtained by reducing the size of the protuberance and lowering the superior brim in this region.

Anterior Side.--The front of the socket is kept snug, but not so tight as to produce pressure over the femoral triangle and thus impair circulation of the stump. In order to maintain suction on short or tapered stumps a slight undercut can be made starting approximately one-half inch below the superior brim, with a long taper downward from the undercut. The slope and height of the anterior side vary in accordance with the needs of the amputee. In cases with short or tapered stumps the anterior side should be as high as necessary to aid in maintaining suction, but should not cause undue pressure while sitting.

Soft Backs

Soft-back sockets are especially recommended for stumps with a very prominent gluteus maximus muscle that requires a deep relief which protrudes posteriorly in the socket and produces an outward rotation of the leg while sitting, as shown in Figure 8. Using a soft back in the gluteus region will correct this condition. Construction of the soft-back socket is essentially the same as that used by limb fitters for the past thirty years. However, the felt padding is not used, in order that the soft back can be kept thin as possible. The inward compression of the soft back while sitting relieves the skin tension about the ischial seat and thus reduces the discomfort experienced by amputees who sit for long periods of time. The principal steps in the construction of the soft-back socket are shown in Figure 9.

Tightness of Fit

Initially, too much emphasis was given to tightness of fit. Better results have been obtained by having proper contours rather than a tight fit. If much difficulty is encountered in removing the thin sock during insertion of the stump into the socket, it is an indication that the fit is too tight. The superior brim of the socket should fit rather snugly; the middle portion of the socket should fit the contour of the stump while tensed, although the fit should not be too tight in this region; and the distal end of the stump should be free but not loose within the socket.

Free Space at End of Stump

The amount of unoccupied volume at the lower end of the socket is not critical with regard to obtaining sufficient suction. In most cases it is convenient to have approximately two inches below the end of the stump to provide space for installation of the valve and room for elongation of the stump muscles. In general, the smaller the volume in the end of the socket the less the excursion; but the amount of free volume in itself has no effect on the magnitude of the negative pressure.

End bearing is recommended if it can be tolerated, since it relieves the load on the ischium. Felt padding placed in the bottom of the socket will permit comfortable end bearing; the thickness of felt padding governs the amount of weight carried on the end of the stump. Although little free space remains in the socket, adequate suction and control are not affected. Gritti-Stokes amputations which were principally end bearing have been very easily and successfully fitted.

Inside Finish

No single recommendation can be made at this time regarding adequate finishes to which the skin is tolerant. Industrial lacquer and flesh enamel paint, thoroughly dried, have each been used; but some subjects have reported slipping in the socket due to perspiration. In some cases perspiration has also caused the lacquer finish to deteriorate, producing particles which cause skin irritation. Paraffine wax has been unsuccessful in most cases tried. A satisfactory finish has been obtained by using a paste

wood-wax with a beeswax base which was installed initially by heating the wood. Cellulose acetate dissolved in acetone has been the most generally successful inside finish.

Bottom Seal

The bottom of the socket should be sealed with a piece of hardwood 1/4 to 1/2 inch thick, cut with the surface along the grain and sealed with a waterproof glue. Soft wood, with large pores in the grain, and plywood are not satisfactory for this purpose.

Valves and Installation

Several different types of valves have been used with good results. A simple plug type with manual release of suction has been satisfactory. Automatic expulsion valves permit some change of air in the socket, which is beneficial during hot weather and times of perspiration. Automatic expulsion valves have proven successful in all cases tried, and they are now in general use. Two types are shown in Figure 10.

The valve opening should be located for ease in removing the thin sock when the leg is being put on, for convenience in operating the valve manual control, and where there is no possibility that the distal end of the stump will contact the inner face of the valve. Most valves have been located toward the front on the medial side and below the stump.

Care should be taken that the valve insert is securely glued in the socket wall and is completely air tight.

The magnitude of negative pressure, or suction, required to hold the socket in place is only slightly greater than the weight of the prosthesis divided by the cross-sectional area of the stump near the distal end. In most cases the weight divided by the area is about $1\frac{1}{2}$ pounds per square inch; and with the additional support given by contracting the stump muscles during each step, a negative pressure of $1\frac{1}{2}$ pounds per square inch should be sufficient. Some amputees prefer somewhat greater suction with its accompanying feeling of security; however, excessive suction may cause edema. A negative pressure greater than $1\frac{1}{2}$ pounds per square inch is an indication that forces are present tending to pull or push the leg off the stump, as indicated at D

ALIGNMENT OF THE SUCTION-SOCKET LEG

In order for the amputee to derive the maximum benefit from the many advantages of the suction-socket leg, such as the decreased feel of weight and greatly increased control of the prosthesis, the leg must be properly and accurately aligned. This accuracy is necessary since the amputee controls the prosthesis by use of the stump muscles alone; poor alignment of the leg cannot be made less apparent, as with the conventional limb, by judicious location and adjustment of the pelvic joint. Therefore, much care and judgment must be exercised in the alignment of the suction-socket leg in order to prevent unnecessary failures.

In general, the alignment of an artificial leg must be evaluated on the basis of observations while the amputee is walking. This requires a space where at least eight steps can be taken. Poor alignment is evidenced by excessive rotation of the foot at heel strike or toe off, whipping of the shank in either the medial or the lateral direction in the swing phase, or lateral instability during the stance phase, all as indicated in Figure 12. Some of the causes of poor alignment such as incorrect knock or bow at the knee may show up in several ways; and correction of one fault may have a detrimental effect upon some other phase of alignment. The correct amount of knock or bow at the knee (angle between the socket and the shank) is that position which results in the greatest comfort and most natural appearing gait for the individual amputee. The problem as to the exact causes of poor alignment has not been completely solved, but experience has shown the following to be the common causes:

1. "Whip" of the Knee in Swing Phase

   This also creates a rotation of the leg at heel strike due to impact torque as leg extends.

   a) Incorrect internal or external rotation of knee bolt.
   b) Incorrect knock or bow in knee.
   c) Incorrect tilt of knee bolt with respect to horizontal.

2. Rotation of the Foot at Heel Strike or Toe Off

   a) Too tight a fit in the socket over the adductor longus muscle.
   b) Incorrect knock or bow in knee.
   c) Ankle joint set at wrong angle in foot.
   d) Toe break not perpendicular to line of progression.

3. Medio-Lateral Instability During Stance Phase

   a) Incorrect knock or bow in knee.
   b) Incorrect "in-set" or "out-set" of foot with respect to socket.

COMMON DIFFICULTIES IN FITTING THE SUCTION SOCKET LEG

In order for the leg to be satisfactory to an amputee it must function properly while the amputee is walking under various conditions, standing, sitting on either hard or soft surfaces, and when the leg is suspended as while entering or leaving an automobile or street car. It is entirely possible for a leg to be perfectly satisfactory under one or more of these conditions and yet totally unsatisfactory for some other function. The major factors which influence the function of the leg are the shape and fit of the socket and the alignment of the socket and leg. Carefully controlled clinical experience with more than 150 cases has shown that errors in fit and alignment can be diagnosed and, when corrected, lead to a successful fitting.

Original Construction

Common errors in the shape and fit of the socket, some of which are shown in Figure 13, are as follows:

1. Ischial seat too large. Results in undue stretching of the skin and a burning sensation in this area while sitting.

2. Edge of ischial seat too sharp. Causes a very sharp indentation of the skin and may be painful. A thin wall on any edge of the superior brim results in a similar condition. The entire edge of the socket should be round and the ischial seat sloped slightly to relieve this condition.

3. Ischial seat too far toward medial side. Too much weight is borne on the ramus of the ischium. This also crowds the adductor muscles into a small area and causes a burning sensation of the skin around the edge of the ischial seat. This burning becomes more apparent as muscle tone improves and the fit becomes tighter.

4. Anterior-posterior dimension too large. The ischial tuberosity tends to slide forward off the ischial seat. The amputee experiences considerable tightness and irritation across the front of the socket; this may erroneously be taken as an indication that wood should be removed from the front of the socket, on the assumption that the anterior-medial apex is too tight. Such removal can only aggravate the condition and result in a complete failure of fit. The difficulty can be avoided by proper measurement of the distance between the adductor longus tendon and the portion of the tuberosity of the ischium which would bear weight, as shown at A in Figure 6. This measurement can then be marked directly on the block and the socket shaped to correspond.

5. Crowding of adductor longus muscle. Tightness over the adductor longus muscle at the medial-anterior apex will cause external rotation of the foot at the time of heel strike.

6. Gluteal channel too large. May cause burning in the region of the ischial seat during standing, since little of the weight is being carried by the gluteal muscle. While the amputee is sitting, the stump is wedged into the channel and causes an effect similar to that experienced with the ischial seat moved too far to the medial side. Such a socket will also tend to rotate the foot and shank outward upon sitting due to the slant of the rear outside surface of the socket.

7. Fit in lower portion of socket too tight. Too tight a fit will result in edema at the end of the stump, as indicated in Figure 15. An extremely tight fit is indicated if there is difficulty in removing the sock while putting on the leg, or if negative pressure above 2 pounds per square inch is developed during the swing phase.

Example of Common Errors.--Figure 14 is a comparison of two wooden sockets made for the same stump. The one shown by the two views A at the left was satisfactory and comfortable; the other shown by the two views B at the right was unsatisfactory and could not be worn. Socket A was finished with cellulose acetate and socket B with flesh enamel paint. Attention is directed to certain errors of shape and construction in the unsatisfactory socket that should be avoided, as follows:

The ischial seat is prolonged too far to the medial side, causing pressure on the ramus and constriction of the adductors.

The width and location of the ischial seat result in lateral displacement of the stump in the socket, with undue pressure on the lateral and distal end of the femur.

The ischial seat is too high with respect to the medial and gluteal channels, resulting in the entire weight being carried on the ischial seat.

The shelf-like form of the ischial seat due to the undercut causes stretching of the skin over the sharp border or edge and results in a burning sensation of the skin.

The gluteal channel is cut too low and is too narrow, causing loss of suction while sitting.

The inside has not been properly finished; the surface is very rough.

Both sockets have filled tack holes left from the rawhiding process. This error should be avoided by sewing the rawhide with a sack needle. The ischial seat should be smooth to produce the greatest comfort in this area.

Use and Adjustments

Stump Growth.--Another source of trouble in the fitting of the suction socket is the growth of the stump as the amputee uses the leg during the first few months. This results in an increase in the tightness of fit and may cause edema if the socket is not enlarged to account for this natural growth of the muscles as they are put to use in manipulating the leg.

The two variables in stump growth are subcutaneous fat and muscle. During the initial period of wearing the leg, the amount of fat decreases whereas the muscles tend to increase in size. The rate of loss of fat is usually more rapid than the rate of muscle growth; hence at first there will be little change or even a slight shrinkage. If sufficient shrinkage occurs to cause loss of suction, a liner should be installed; but this liner should be removed when it is no longer required. Eventually the muscular development will generally result in a net growth; and material should be provided for increasing the size of the socket. The greatest increase in stump size will occur if the muscles are flabby and the fat is thin.

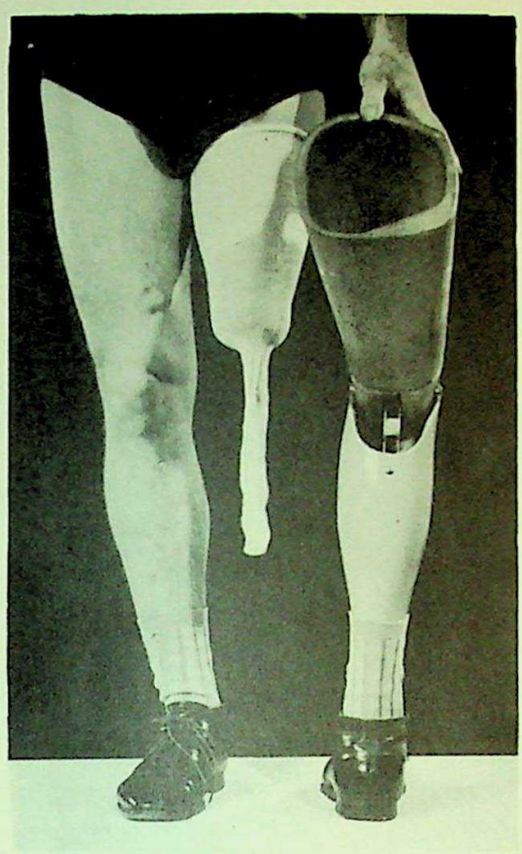
Alignment.--All of the factors causing poor alignment of the leg as previously described can be observed in many suction-socket legs. However, the faults most commonly encountered are excessive external rotation of the knee bolt, resulting in a medial whip of the foot; insufficient knock in the knee, causing whip, lateral instability, and external rotation of the foot upon heel contact; and the toe break not set perpendicular to the line of progression with resulting rotation of the leg during push-off.

Edema.--Edema is most commonly encountered as a result of too tight a fit below the brim of the socket, as indicated at A and B in Figure 15. However, edema may be due to capillary fragility if the fit is not correct. The patient should be tested for capillary fragility either by means of the suction-cup petechiometer or by the blood-pressure cuff test. Capillary fragility varies with the thickness of the skin over various parts of the body. In a few cases, capillaries have been found to be very fragile at the superior brim although not fragile below this level; in most cases capillary fragility has been negative below the upper third of the thigh. Vitamin C deficiency is a major cause of capillary fragility, and if it is discovered the patient should be supplied with Vitamin C. However, one mid-thigh amputation with marked capillary fragility has been fitted without correction of the deficiency with no subsequent development of edema or petechial hemorrhages. Success with this patient was attributed to the accuracy of the socket fit.

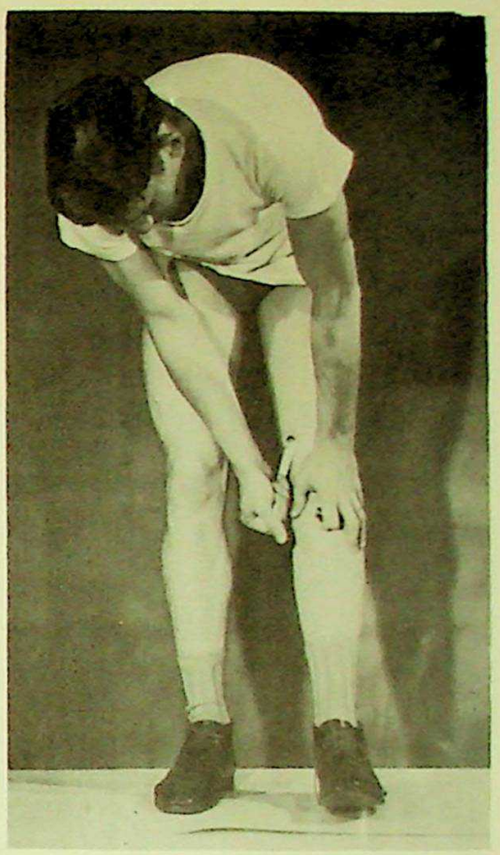
Perspiration.--Perspiration has been a minor problem to date. Where it is excessive, silica gel crystals may be placed in the bottom of the socket to absorb the moisture. Silica gel can be purchased from any drug store. The crystals should be placed in a small cloth sack, such as a "Bull Durham" sack, and placed in the bottom of the socket. If perspiration is excessive at least two sacks may be necessary, the one not in use being placed in a hot dry place to drive off moisture and make it ready for re-use.

(Figures 1-15 follow)

I L L U S T R A T I O N S

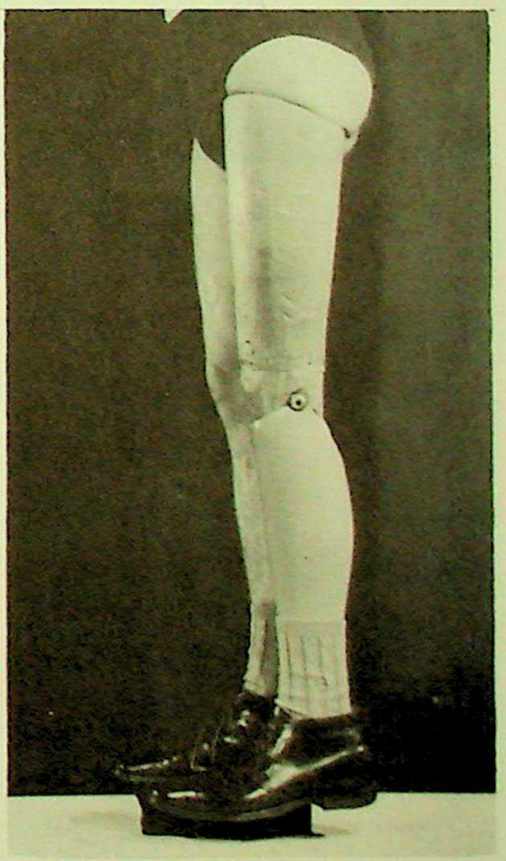


A. STOCKINETTE ON STUMP



B. REMOVAL OF STOCKINETTE

C. INSERTION OF VALVE



D. LEG SUSPENDED BY NEGATIVE PRESSURE

FIG. 1- PROCEDURE FOR PUTTING ON SUCTION-SOCKET LEG

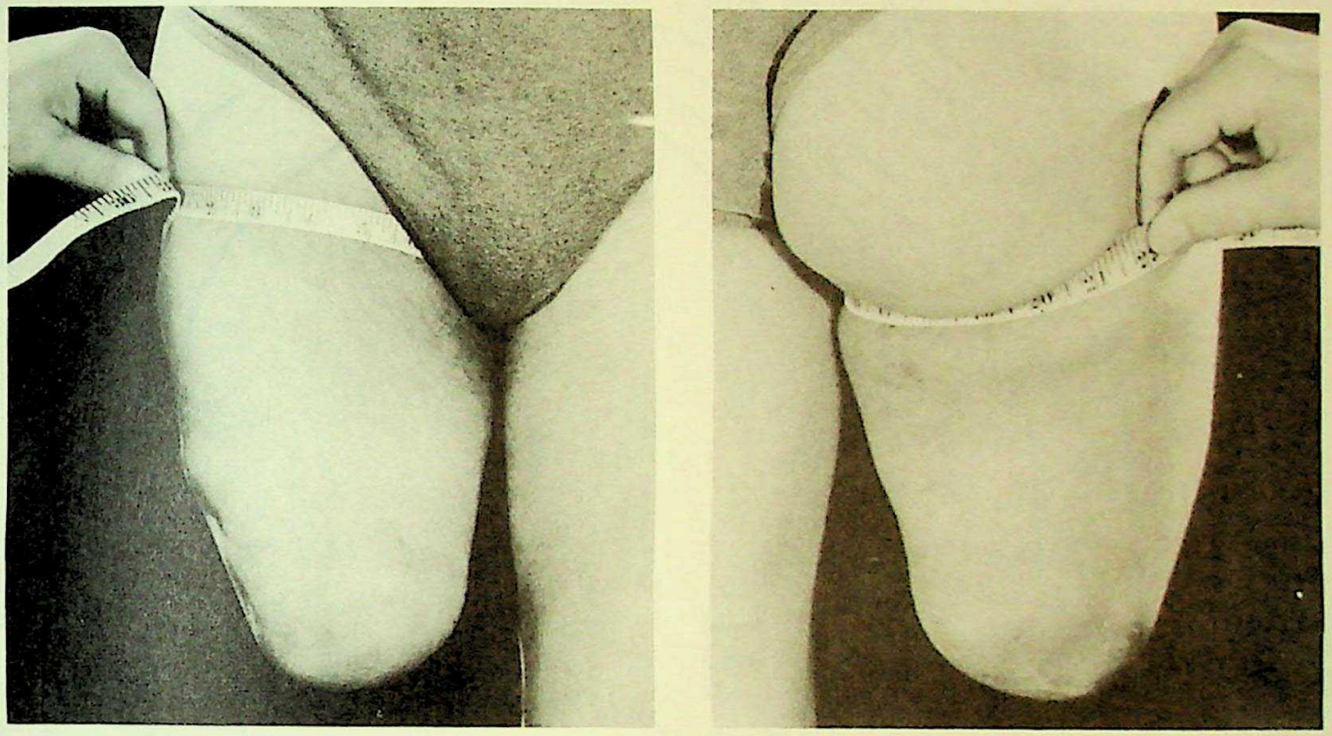


FIG. 2 - PERIMETER MEASUREMENT FOR DETERMINING PATTERN SIZE

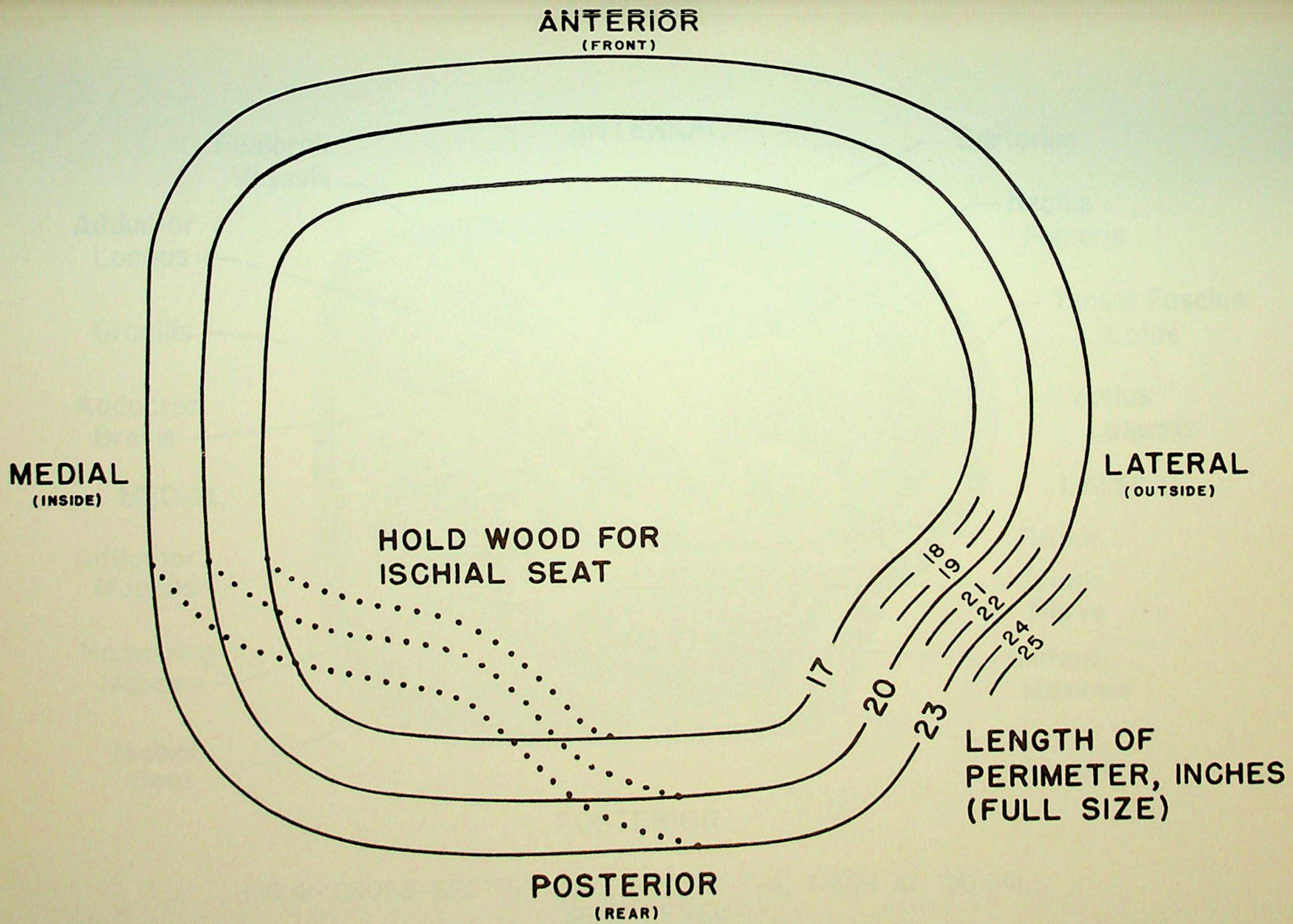


FIG. 3 — CROSS-SECTION PATTERNS AT ISCHIAL-SEAT LEVEL

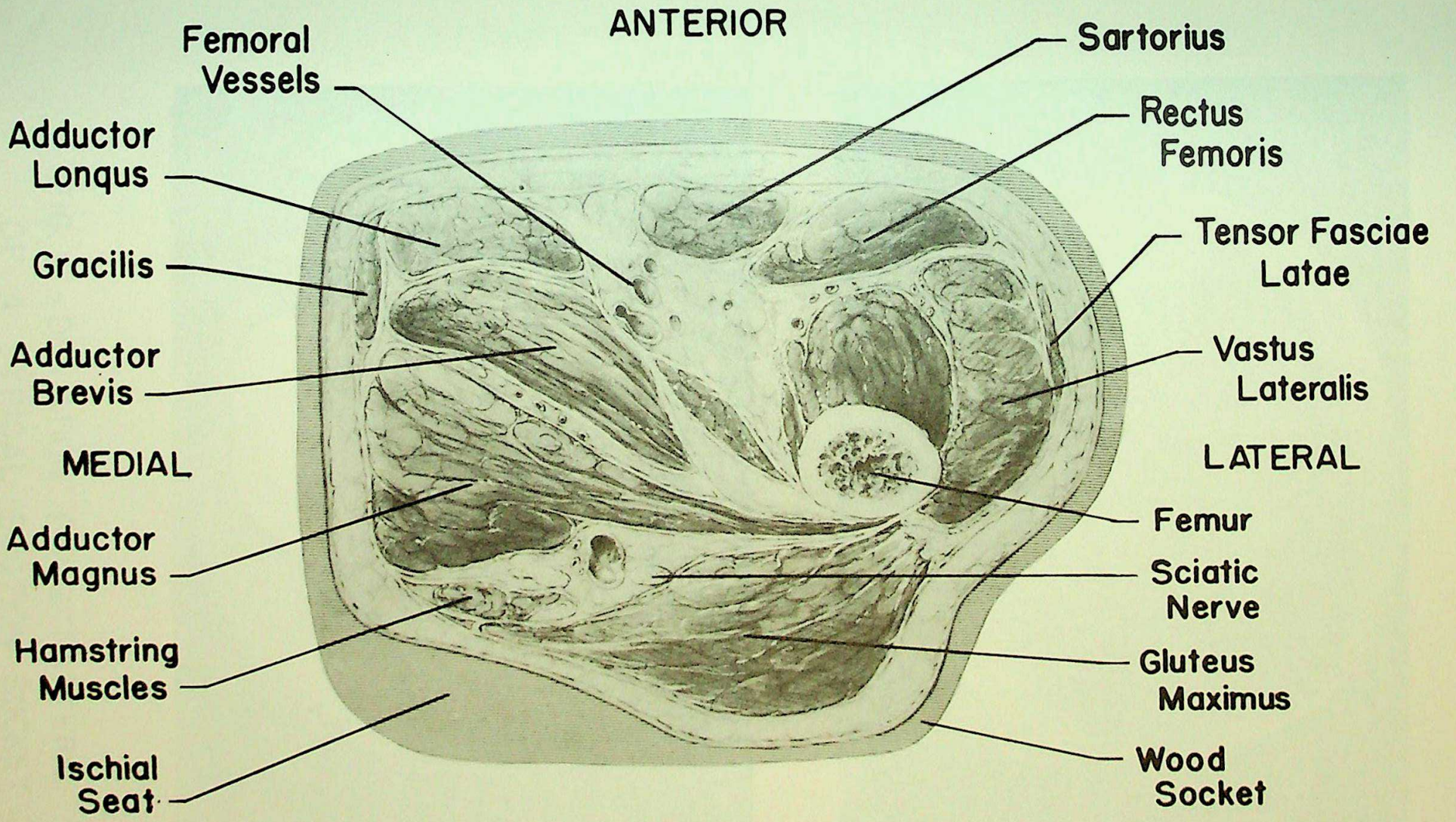
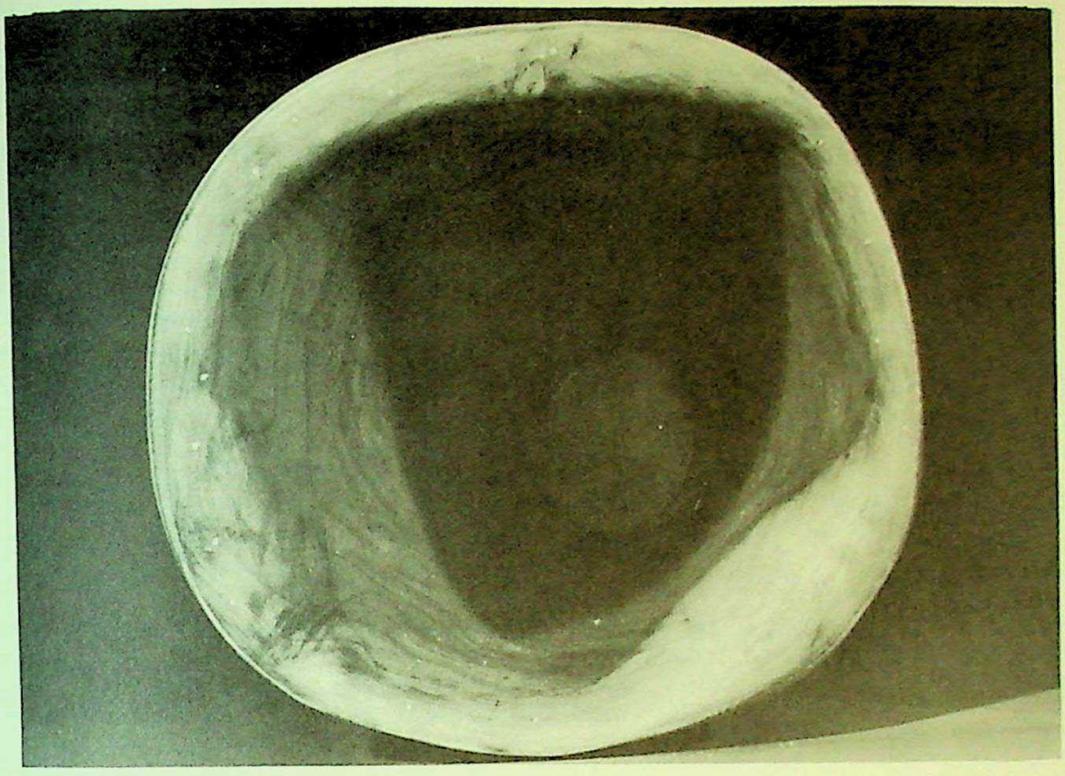


FIG. 4 – CROSS-SECTION ANATOMY OF THE THIGH AT ISCHIAL SEAT LEVEL



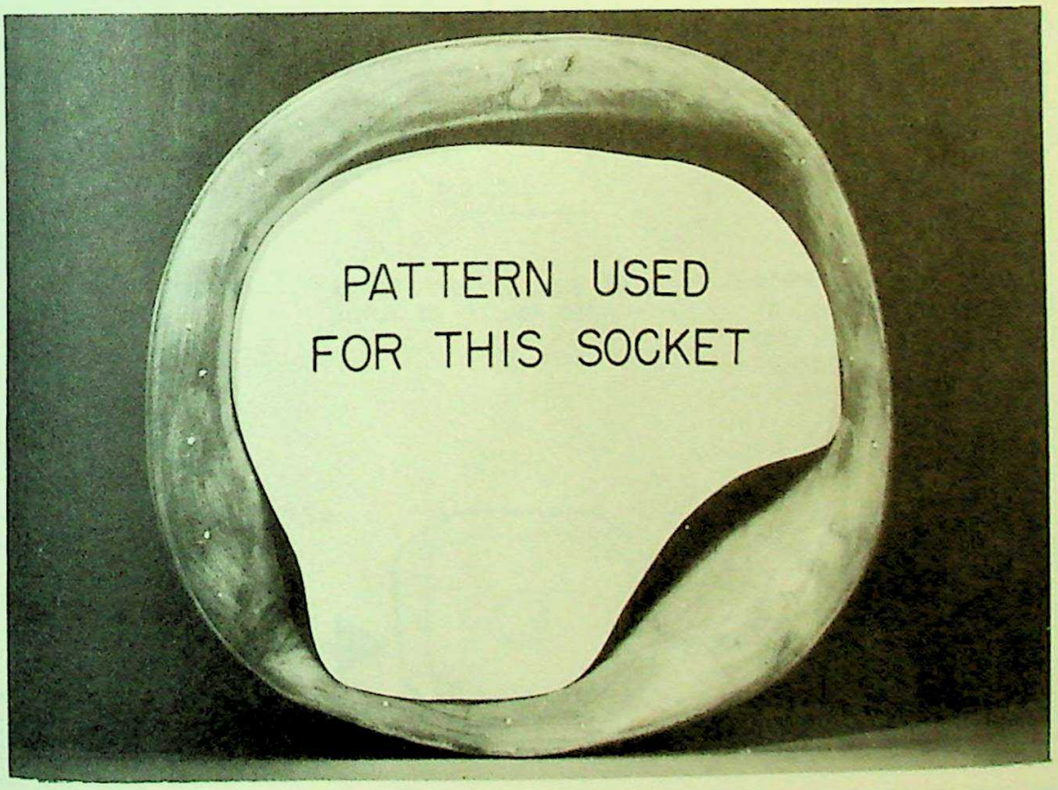
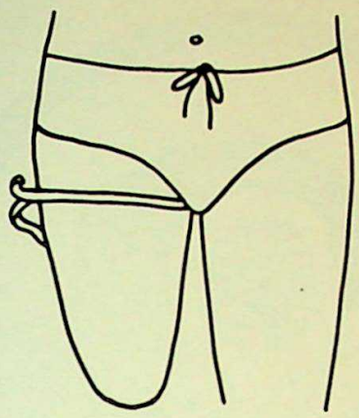
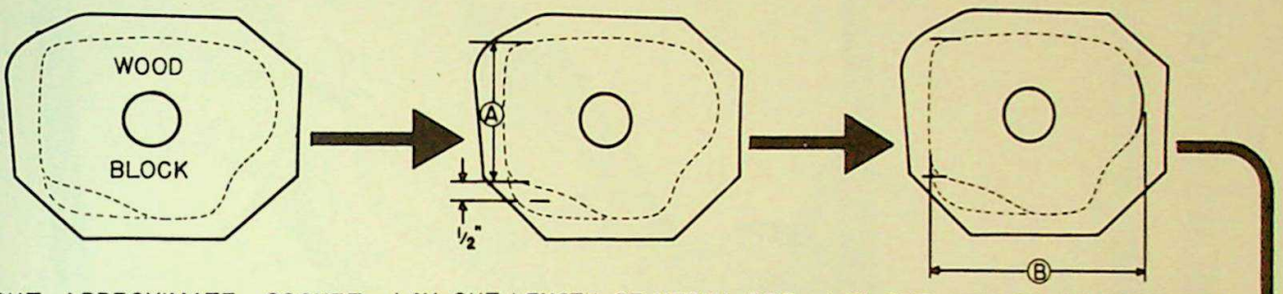


FIG. 5 - DEVIATION FROM PATTERN
OF A TYPICAL SUCTION SOCKET



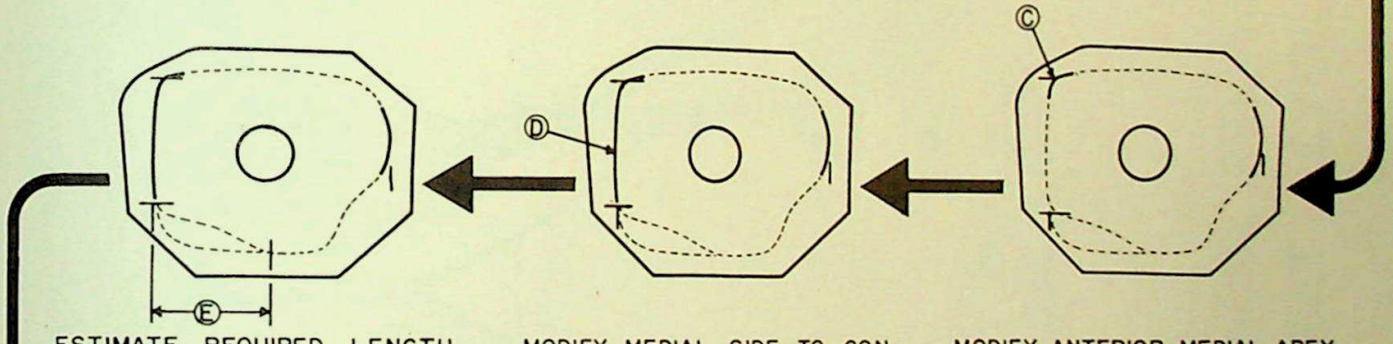
THE SOCKET IS STARTED BY MEASURING THE STUMP PERIMETER AT THE ISCHIAL SEAT LEVEL TO DETERMINE THE APPROXIMATE PATTERN SIZE.



LAY OUT APPROXIMATE SOCKET OUTLINE FROM PATTERN. MAKE ALTERATIONS IF NECESSARY AS SHOWN IN THE FOLLOWING ILLUSTRATIONS.

LAY OUT LENGTH OF MEDIAL SIDE AS ½" LESS THAN DISTANCE FROM ANTERIOR-MEDIAL APEX TO ISCHIAL TUBEROSITY-Ⓐ.

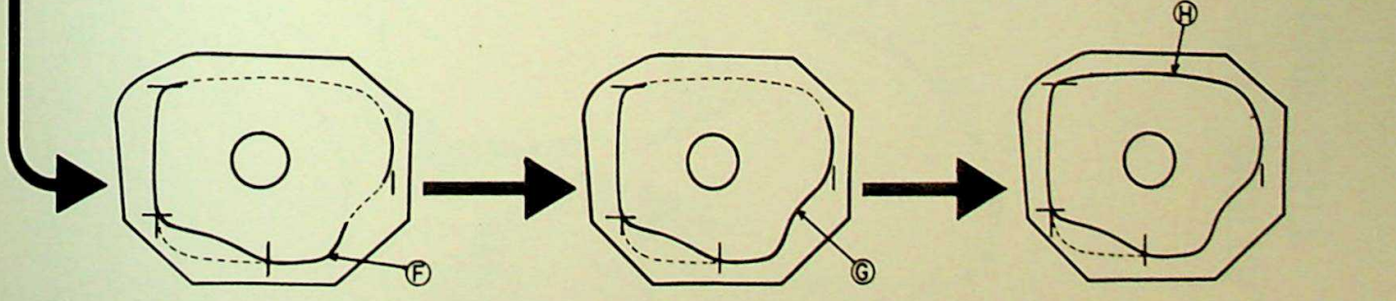
LAY OUT LENGTH OF POSTERIOR SIDE EQUAL TO MAX. LATERAL-MEDIAL STUMP MEASUREMENT-Ⓑ.



ESTIMATE REQUIRED LENGTH OF ISCHIAL SEAT -Ⓔ.

MODIFY MEDIAL SIDE TO CONFORM TO STUMP CONTOUR-Ⓓ.

MODIFY ANTERIOR-MEDIAL APEX TO CONFORM TO STUMP CONTOUR WITH ADDUCTOR LONGUS TENSED-Ⓒ.



MODIFY GLUTEAL AREA TO CONFORM TO STUMP CONTOUR-Ⓕ.

ADD PROTUBERANCE ON LATERAL SIDE IF NECESSARY-Ⓖ.

MODIFY ANTERIOR SIDE TO CONFORM TO STUMP CONTOUR-Ⓗ.

FIG. 6-PRELIMINARY LAYOUT OF THE SUCTION-SOCKET OUTLINE

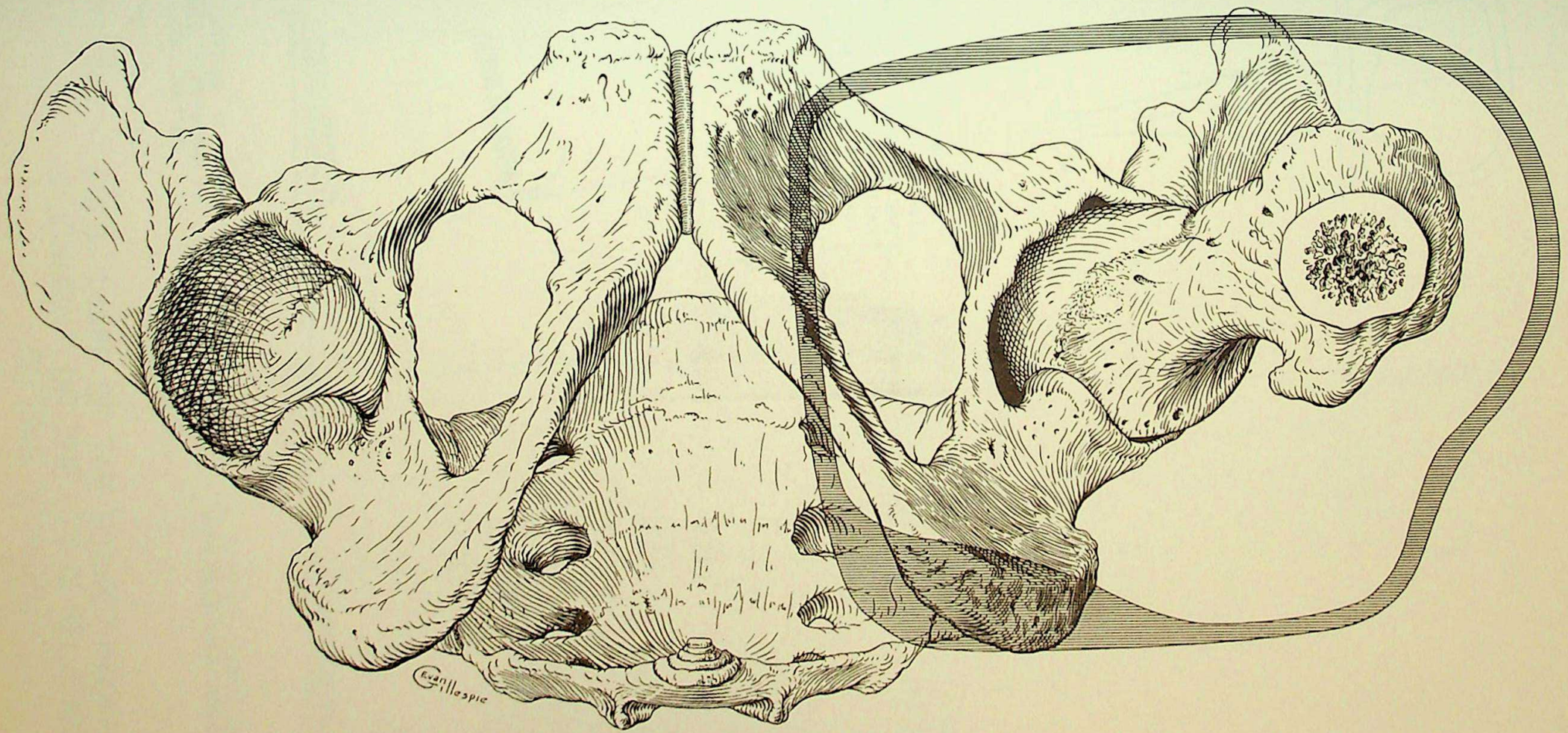
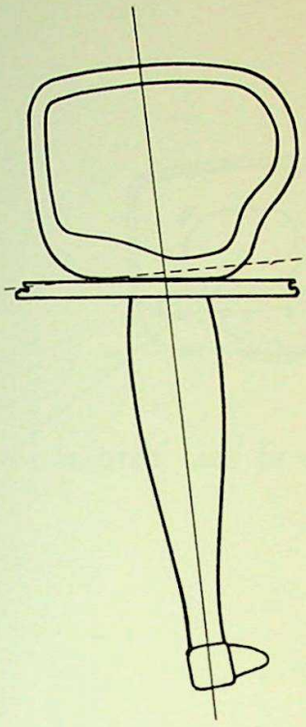
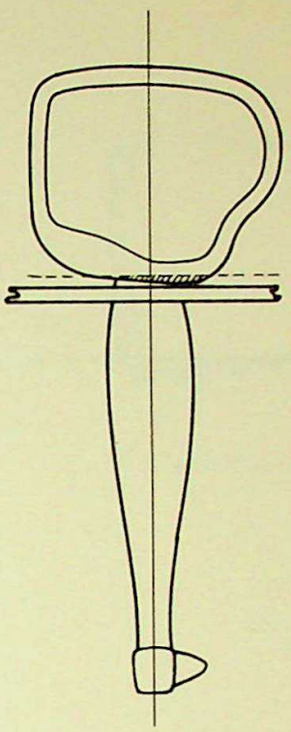


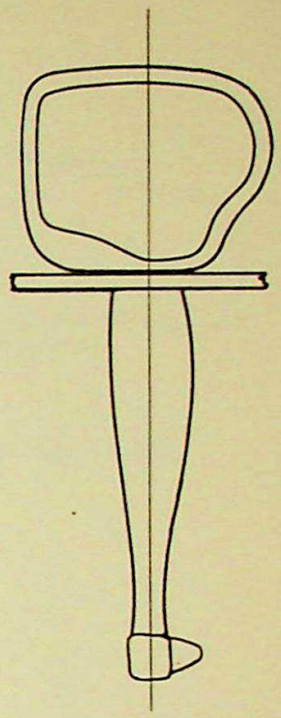
FIG. 7 – RELATION OF THE BONY PELVIS TO THE SUCTION SOCKET AT THE ISCHIAL SEAT LEVEL, AS VIEWED FROM BELOW



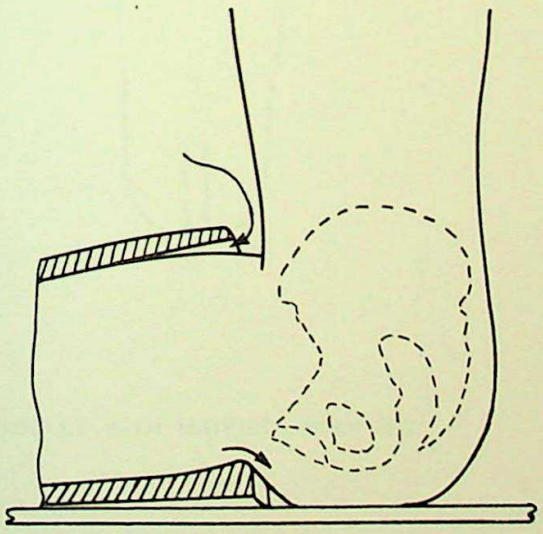
A. FOOT OFTEN ROTATED OUTWARD WHEN SITTING ON HARD SURFACES DUE TO SOCKET SHAPE. NECESSARY TO SHAPE SOCKET BACK AFTER WALKING ALIGNMENT IS OBTAINED.



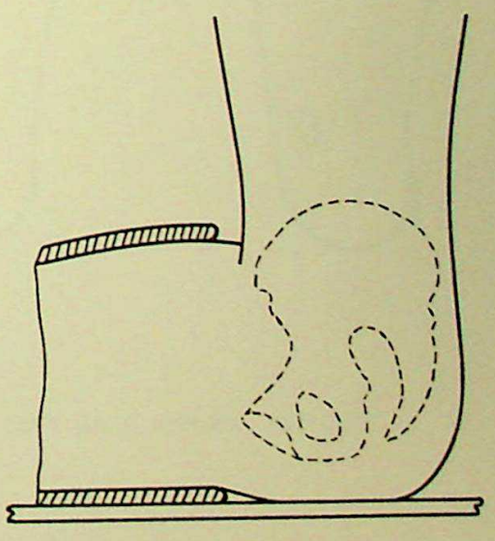
B. FOR PROPER SITTING ALIGNMENT, REMOVE EXCESS WOOD AS INDICATED.



C. PROPER SITTING ALIGNMENT. THICKNESS OF WALL CONSISTENT WITH STRENGTH.

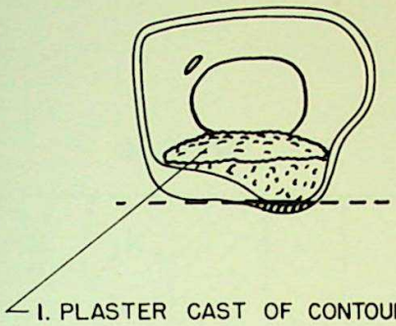


D. ELEVATION OF ISCHIAL SEAT WHILE SITTING CAUSES STRETCHING OF SKIN AND MAY CAUSE LOSS OF SUCTION.

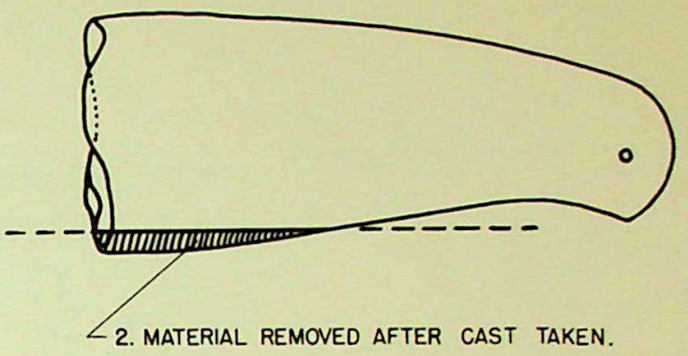


E. PROPERLY SLOPED AND ROUNDED ISCHIAL SEAT WITH FLAT BACK IMPROVES SITTING COMFORT.

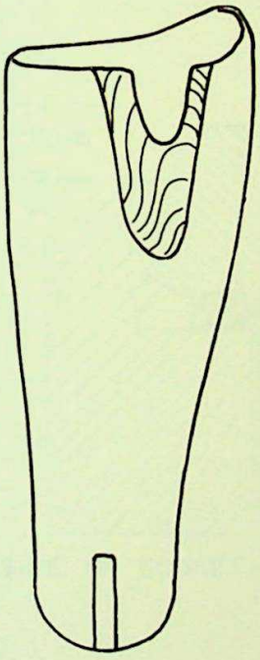
FIG.8 - SHAPE OF THE SOCKET BACK AND ALIGNMENT OF THE LEG IN RELATION TO SITTING COMFORT



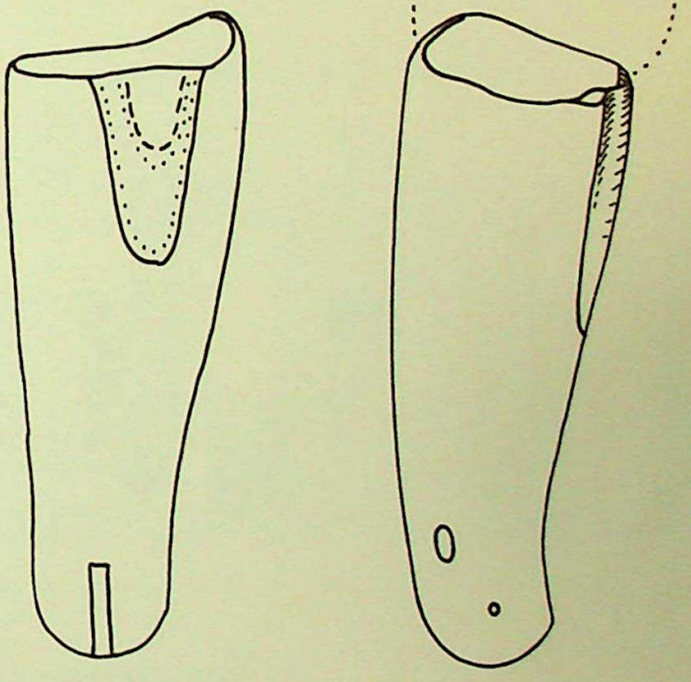
1. PLASTER CAST OF CONTOUR.



2. MATERIAL REMOVED AFTER CAST TAKEN.



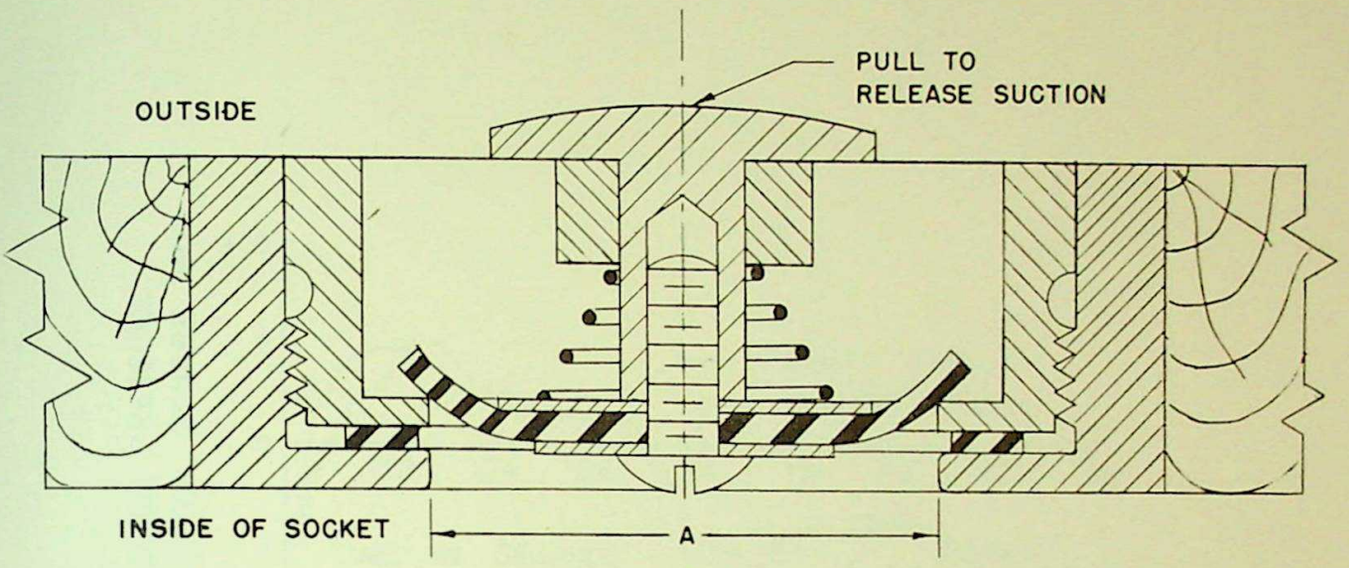
3. SOCKET WITH MATERIAL REMOVED.

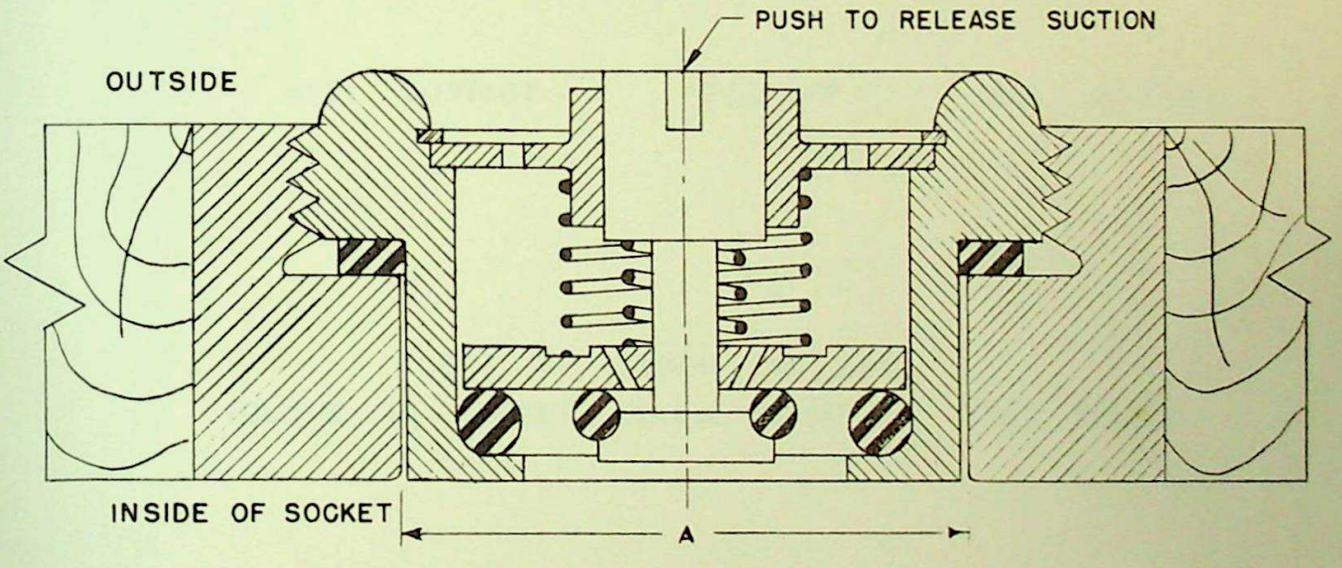


4. SOFT BACK APPLIED. SEE TEXT.

FIG. 9 - CONSTRUCTION OF SOFT-BACK SUCTION SOCKET

USED FOR MUSCULAR STUMPS WITH LARGE GLUTEUS TO INCREASE SITTING COMFORT

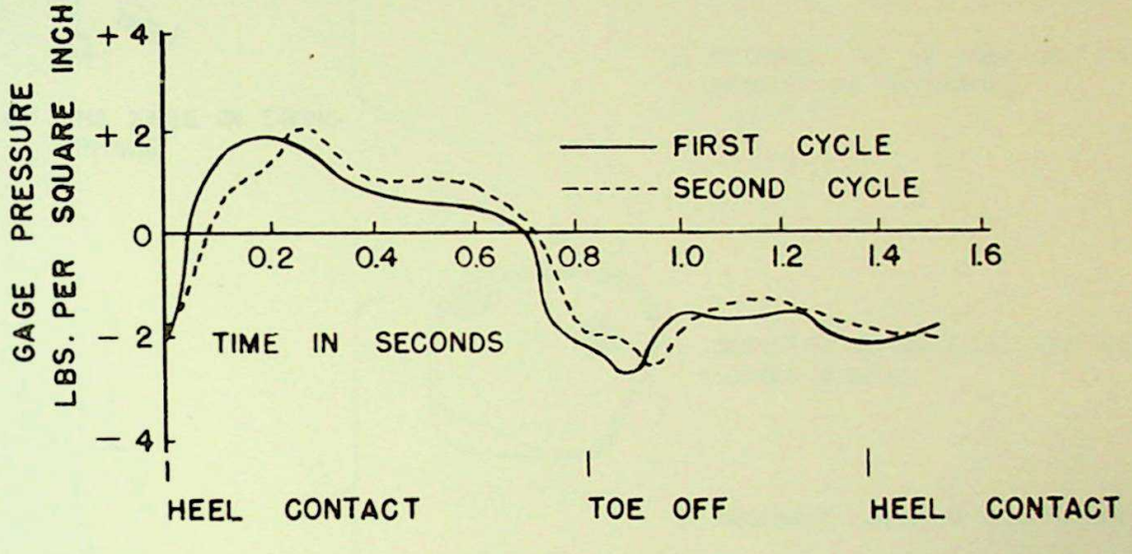




RECOMMENDED STANDARD SIZE

DIMENSION	VALUE
A	0.80 IN.
THREAD	$1\frac{1}{8}$"-16NS-2

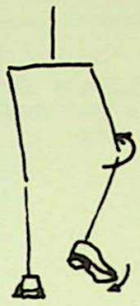
FIG. 10 - TYPICAL AUTOMATIC EXPULSION VALVES FOR SUCTION SOCKETS



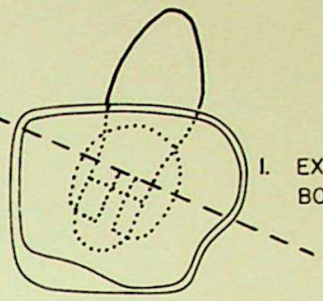
LEFT AK, WEIGHT 145 LBS.
VOLUME IN SOCKET BELOW STUMP = 6 CUBIC INCHES.

FIG. 11 – PRESSURE VARIATION INSIDE A SUCTION SOCKET DURING LEVEL WALKING

INDICATIONS



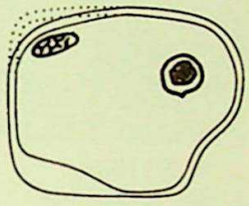
"WHIP" OF THE KNEE IN SWING PHASE

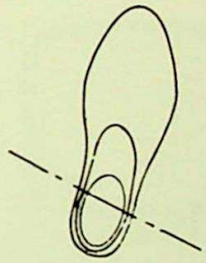


COMMON CAUSES

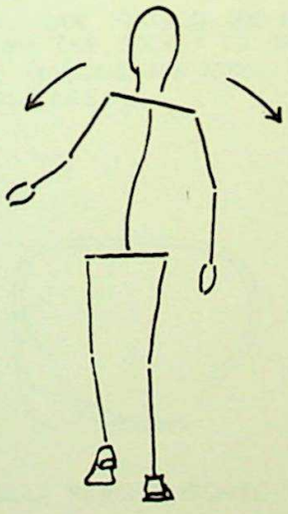
1. EXCESSIVE EXTERNAL ROTATION OF KNEE BOLT.
2. INCORRECT KNOCK OR BOW IN KNEE.
3. INCORRECT TILT OF KNEE BOLT WITH RESPECT TO HORIZONTAL.

ROTATION OF THE FOOT AT HEEL STRIKE





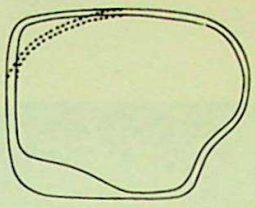
1. SOCKET FITTED TOO TIGHT OVER ADDUCTOR LONGUS MUSCLE.
2. INCORRECT KNOCK OR BOW IN KNEE.
3. ANKLE JOINT SET AT WRONG ANGLE IN FOOT.



MEDIAL–LATERAL INSTABILITY DURING STANCE PHASE

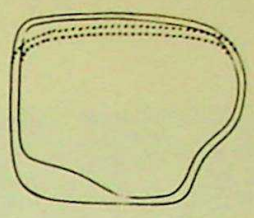
1. INCORRECT KNOCK OR BOW IN KNEE.
2. INCORRECT "IN-SET" OR "OUT-SET" OF FOOT WITH RESPECT TO SOCKET.

FIG. 12 – SOME INDICATIONS OF POOR ALIGNMENT AND THEIR COMMON CAUSES



A

CROWDING THE MUSCLES IN THE ANTERIOR-MEDIAL APEX, CAUSING PAIN AND EXTERNAL ROTATION OF THE FOOT AT HEEL STRIKE.

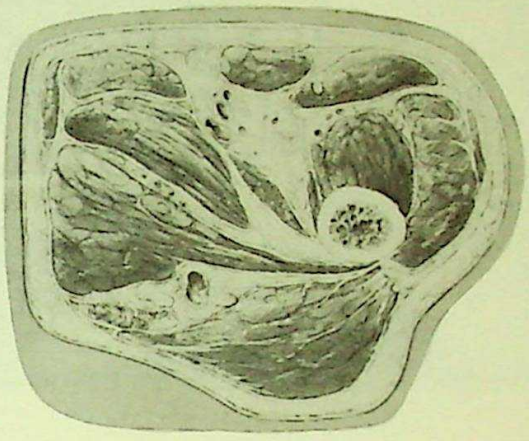


B

TOO TIGHT ANTERIOR REGION, POSSIBLY CAUSING EDEMA.

ANTERIOR

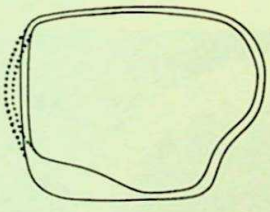
MEDIAL



LATERAL

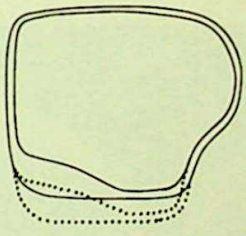
POSTERIOR

GENERAL OUTLINE OF SUCTION SOCKET



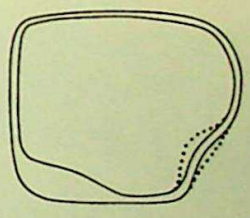
C

MEDIAL SIDE FLARED TOO MUCH, CAUSING THE SOCKET TO SHIFT WHILE WALKING, IRRITATING THE MEDIAL AREA.



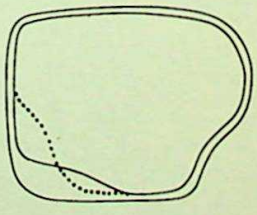
D

ANTERIOR-POSTERIOR DIMENSION TOO GREAT, ALLOWING THE ISCHIAL TUBEROSITY TO FALL INSIDE OF ISCHIAL SEAT, MAKING SOCKET VERY PAINFUL.



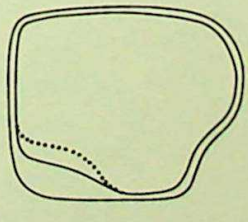
E

TOO LARGE OR TOO SMALL A PROTUBERANCE, CAUSING LOSS OF SUCTION IN SOME STUMPS.



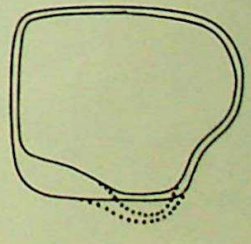
F

MEDIALLY PLACED ISCHIAL SEAT.



G

TOO LARGE ISCHIAL SEAT.



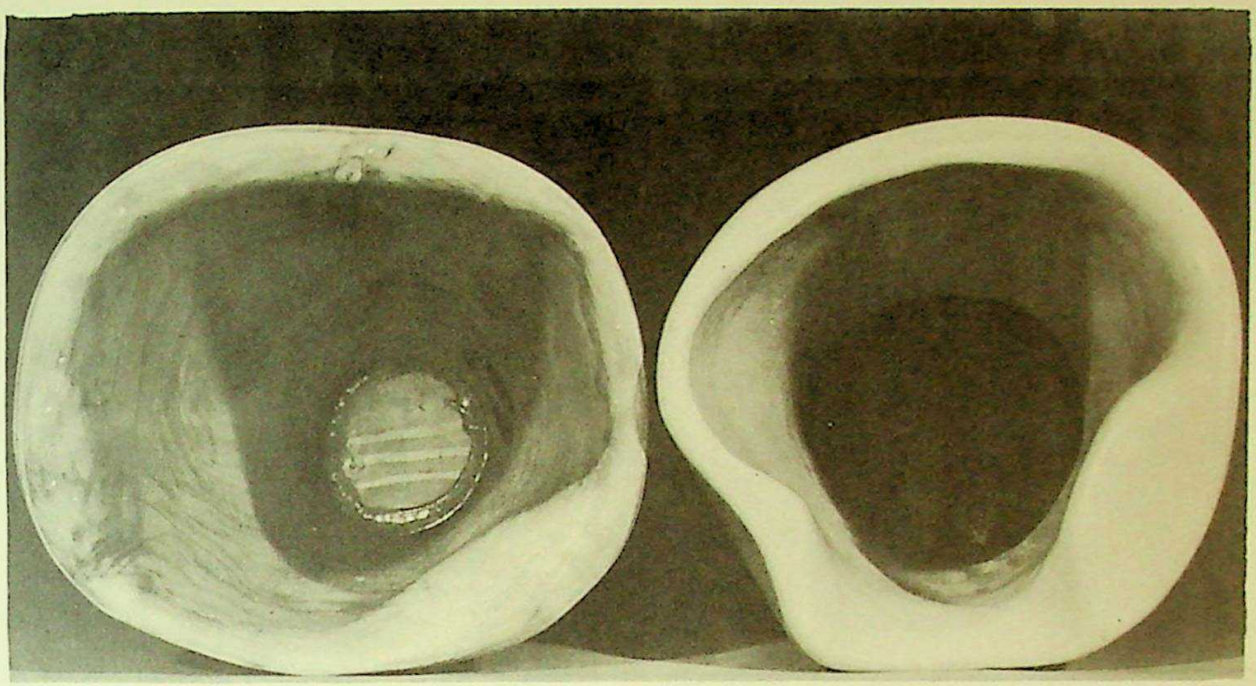
H

TOO LARGE GLUTEUS RELIEF.

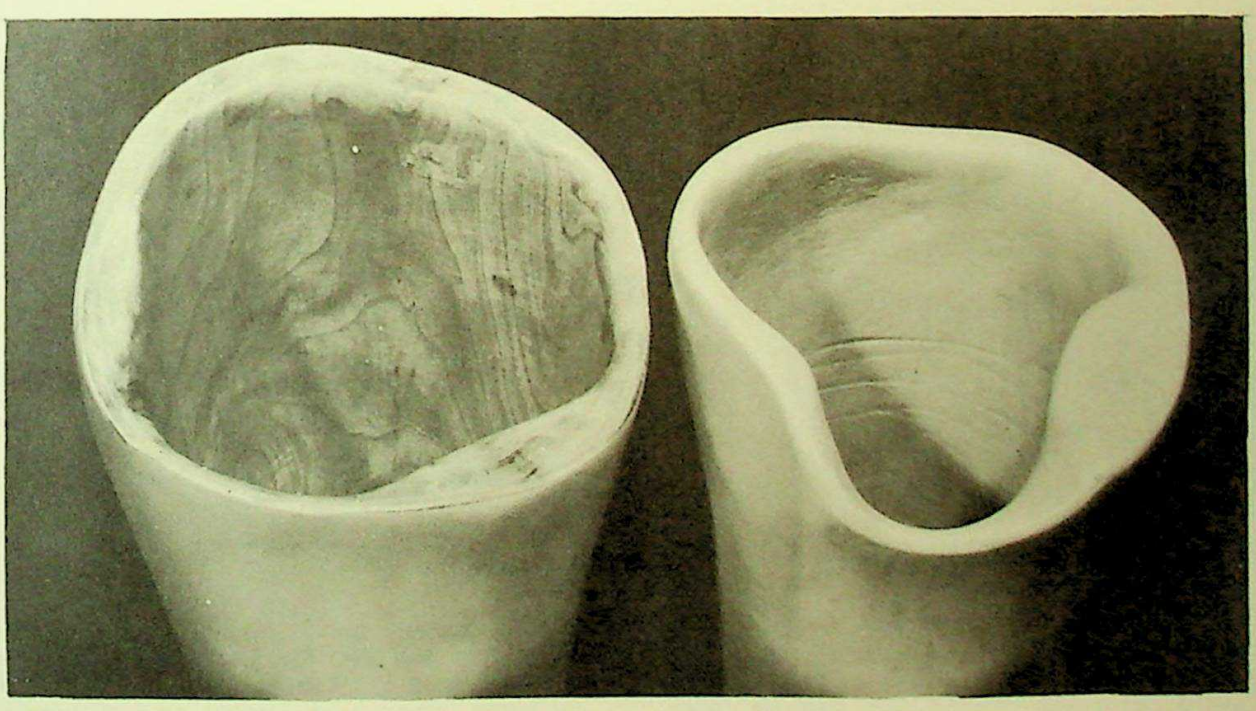
CAUSE OF BURNING SENSATION WHILE SITTING DUE TO STRETCHING THE SKIN.

FIG. 13 - COMMON ERRORS IN FIT AT TOP OF SOCKET

ERROR INDICATED BY DOTTED LINES

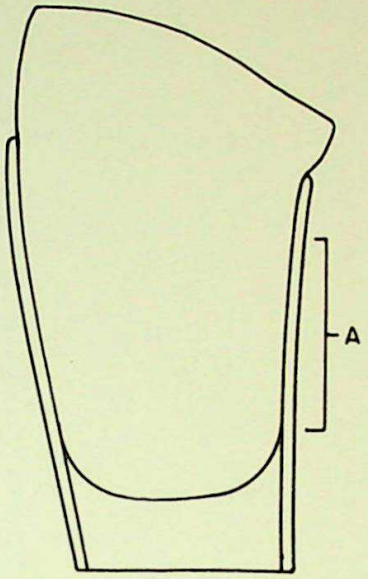


A B

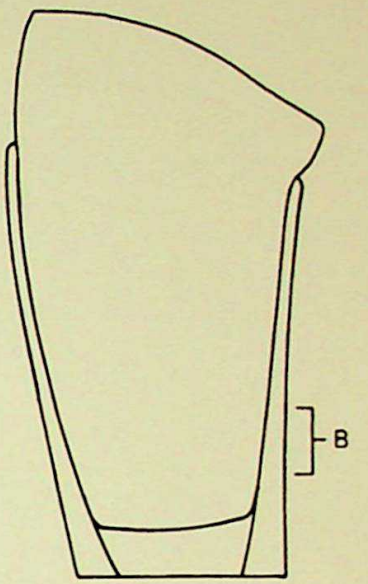


A B

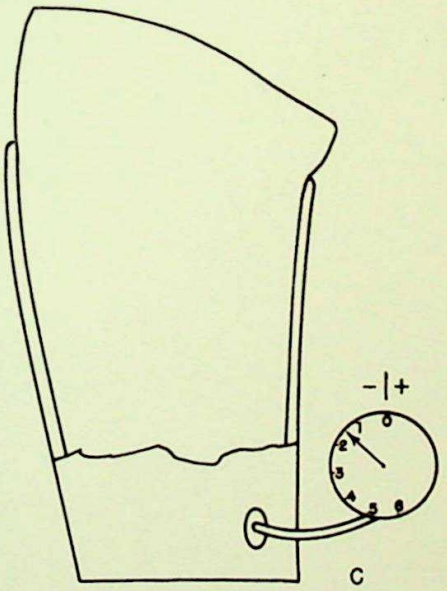
FIG. 14 - SATISFACTORY (A) AND UNSATISFACTORY (B) SUCTION SOCKET FOR THE SAME STUMP



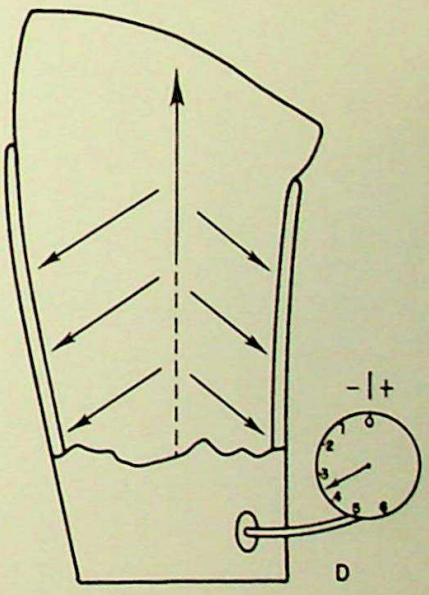
A.- TIGHT FIT IN THIS AREA WILL CAUSE EDEMA WHEN STUMP MUSCLES ARE CONTRACTED AS SHOWN IN D.



B. - CONE-SHAPED BOTTOM WILL CAUSE EDEMA BY CHOKING THE DISTAL END OF THE STUMP.



C. - NEGATIVE PRESSURE OF ONE AND ONE-HALF POUNDS PER SQUARE INCH WILL SUCESSFULLY SUSPEND THE LEG. EDEMA MAY OCCUR WITH AN INCORRECT FIT AS IN A OR B.



D.- A HIGH NEGATIVE PRESSURE INDICATES A VERY TIGHT FIT, PRODUCING FORCES TENDING TO PUSH THE LEG OFF. THE SOCKET MUST BE ENLARGED IMMEDIATELY.

FIG.15 - ERRORS IN FIT BELOW BRIM OF SOCKET

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